Diesel Railway Traction

Partial Hydraulic Transmissions

AS we announce exclusively in another part of this Supplement, a well-known British transmission engineering firm has taken over the rights of the Voith turbo-hydraulic drive which has already given excellent service in the numerous **90** and **180** b.h.p. Austro-Daimler petrol railcars running on the Austrian Federal Railways and other Continental lines. Resembling the Lysholm-Smith gear fitted to the Leyland diesel cars, which we also describe in this issue, the Voith-Sinclair turbo-converter uses direct drive on what may be termed top gear, although in reality it can be used at almost any speed, depending upon the train weight and gradient. The turbo-converter, itself, is much more than merely a bottom gear, and, depending upon the resistance to be overcome, can be economically used at speeds up to about two-thirds of the maximum. Although appearing somewhat complicated from a drawing, both the above gears have proved remarkably free from maintenance troubles, and when inspecting the Leyland car on the L.M.S.R. (Northern Counties Committee) recently, we were informed that absolutely nothing had been done to the torque converter, and it had not even been thought necessary to inspect the interior. Similar results have been obtained with the Austro-Daimler units. We have more than once suggested that the high-power diesel locomotive of the future will be fitted with a combination of direct drive and electric or pneumatic transmission, the latter for use at high torque periods, but in view of the performance of the Voith-Sinclair and Lysholm-Smith drives, it appears that, as far as railcars are concerned, hydraulic media have a distinct future.

Oil-Electric-Battery Locomotives

THERE has hitherto been a great deal of misconception as to what type of duty constituted the economical scope of the three-power locomotive, and as evinced by the correspondence published in these columns in the first half of last year, there appear to be two schools of thought; first, that which considers the useful field of the battery to be largely limited to working in warehouses and occasional peak loads; secondly, that which believes numerous peak loads of short duration and occasional runs on the line are well within the three-power locomotive's capacity. The extensive experience of the New York Central Lines with this type of motive power has enabled the economical sphere of operation to be determined within fairly close limits, and we are fortunate in being able to publish in another part of this issue, through the courtesy of Mr. H. A. Currie, the N.Y.C. Electrical Engineer, a comprehensive article on the operation and maintenance of the **36** locomotives working on the lines in and around New York City. Steam locomotives are prohibited within this area, and to obviate the difficulty and enormous expense of electrifying a large track mileage (overhead gear would have been necessary in the yards, although the N.Y.C. use only **600**-volt d.c.), diesel locomotives of this special type were introduced.

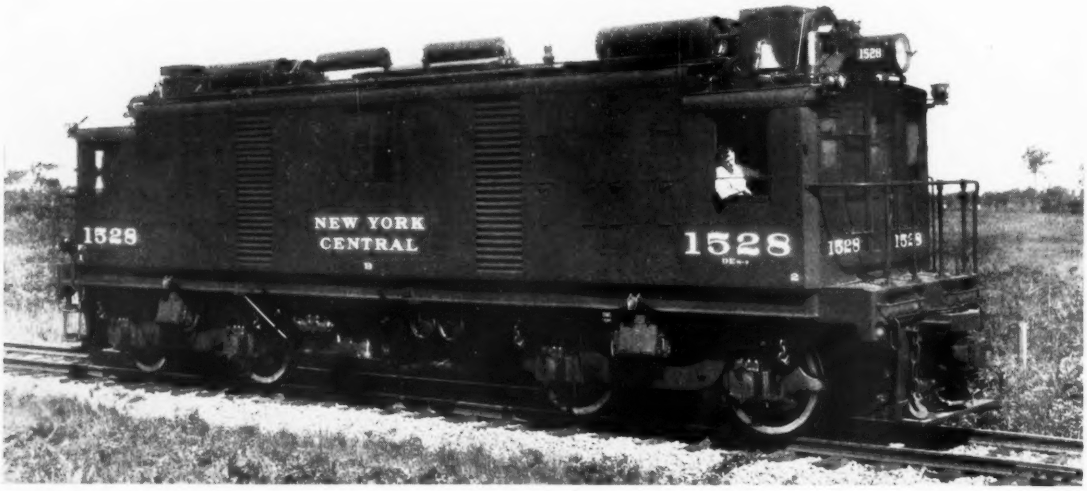
When considering the data presented on maintenance costs and operation, it is important to bear in mind the instructions of the Interstate Commerce Commission. The rules of this body require an inspection of locomotives once each day, and a much more extensive inspection once each month, which takes at least a day. Another point to be emphasised is the meaning of the term " trick " —nautical in English but amphibious in America—which is frequently used in the article. This is simply an eight-hour shift, but where the working periods are longer or shorter than this period they have been converted into eight-hour tricks when tabulating the data.

A Survey of Railcar Development

SUMMARISED elsewhere in this issue is a paper entitled " Railcars," which was delivered by Mr. J. S. Tritton yesterday before the Institution of Locomotive Engineers. Mr. Tritton was very fair in his estimate of the advantages of the several types of railcar available, namely, diesel-electric, diesel-mechanical, petrol, and steam ; and there is little in his paper to which anyone could take exception apart from the remark that electrical transmission is five to seven times as heavy as hydraulic transmission. We do dissent from this. Hydraulic transmissions in the past have been at least as heavy as electric transmission, and we should be surprised to hear that the modern hydraulic transmission had done more than cut the weight figure for electric transmission in half. We wish that the author could have gone so far aside from his attitude of impartiality as to discredit the idea still held in many quarters that the diesel engine is less developed and less to be relied upon than the petrol engine. One of the best known makers of internal-combustion railcars and locomotives has reported to us that many customers still insist on the petrol engine and refuse to have anything to do with the diesel until further time has elapsed. We would point out that the diesel engine is long past its teething stage, and that for this, thanks are due very largely to those operators who have had the courage to nurse it through its early years. These operators, we are glad to say, have been rewarded for their enterprise and are now reaping very substantial benefits in the shape of diminished operating expenses. That the use of petrol engines adds enormously to the terrors of an accident has been made painfully evident only this week. A collision between a petrol railcar and a train in Italy last Sunday resulted in the burning to death of a large proportion of the railcar passengers. Mr. Tritton's plea that the railcar be viewed as a complete breakaway from traditional railway practice deserves respect. In the past, railway engineers familiar with the lightness of automobile construction have nevertheless shown a want of faith in anything that was not from two to five times as heavy. The author rightly remarked that automobile practice was not acceptable in its entirety to the railways, but he was pleased to note that the railways were now giving railcar builders with automobile experience an opportunity to discover for themselves the essential differences between road and railway conditions.

THREE-POWER LOCOMOTIVES

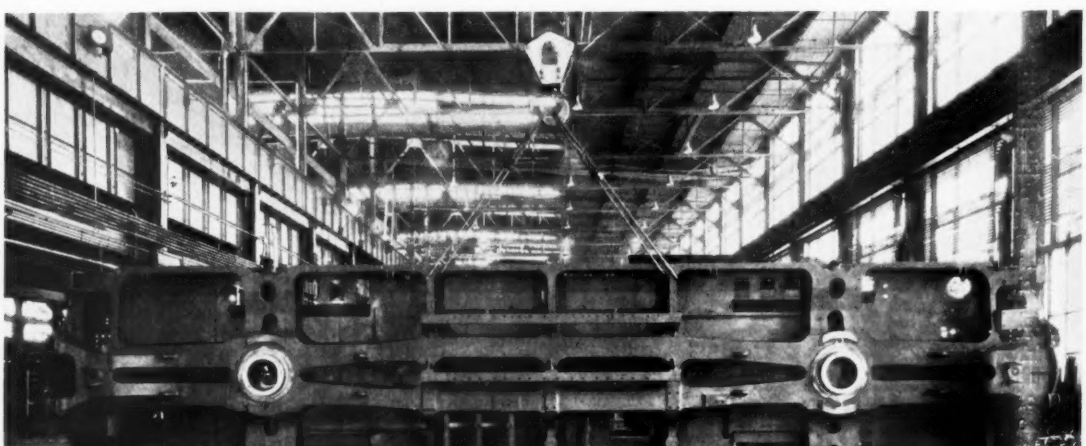
Important operating data have been obtained from the 45 oil-electric-battery locomotives of the New York Central Railroad



Oil-electric-battery shunting locomotive, New York Central Railroad

IN the issue of the *Diesel Railway Traction Supplement* for February 24, 1933, an article was published on the principles and possibilities of the oil-electric-battery locomotive, and in the May 19, June 16, July 14, and August 11 issues we published some of the correspondence we had received on this subject, and which related largely to the units working on the New York Central and Delaware, Lackawanna & Western Railroads. The operating data relative to the N.Y.C. locomotives, which we now present through the courtesy of Mr. H. A. Currie, Electrical Engineer of the N.Y.C., and his assistant, Mr. W. S. H. Hamilton, should therefore be of unusual value, and its importance is enhanced in that it is not drawn up from observations upon a single machine, but is collected from 36 locomotives engaged in the same type of service in and around New York City.

The N.Y.C. and associated lines now have a total of 42 of these locomotives, and there are another seven in operation on other American railroads. Those on the D.L. & W. Railroad have overhead collecting gear suitable for 3,000 volts d.c., and were illustrated and described in the issue of this Supplement for November 3 last. All



One-piece cast steel underbed, New York Central locomotive

except four of the 49 locomotives have Ingersoll-Rand engines, the four in question being powered by Buda engines.

Locomotive Proportions

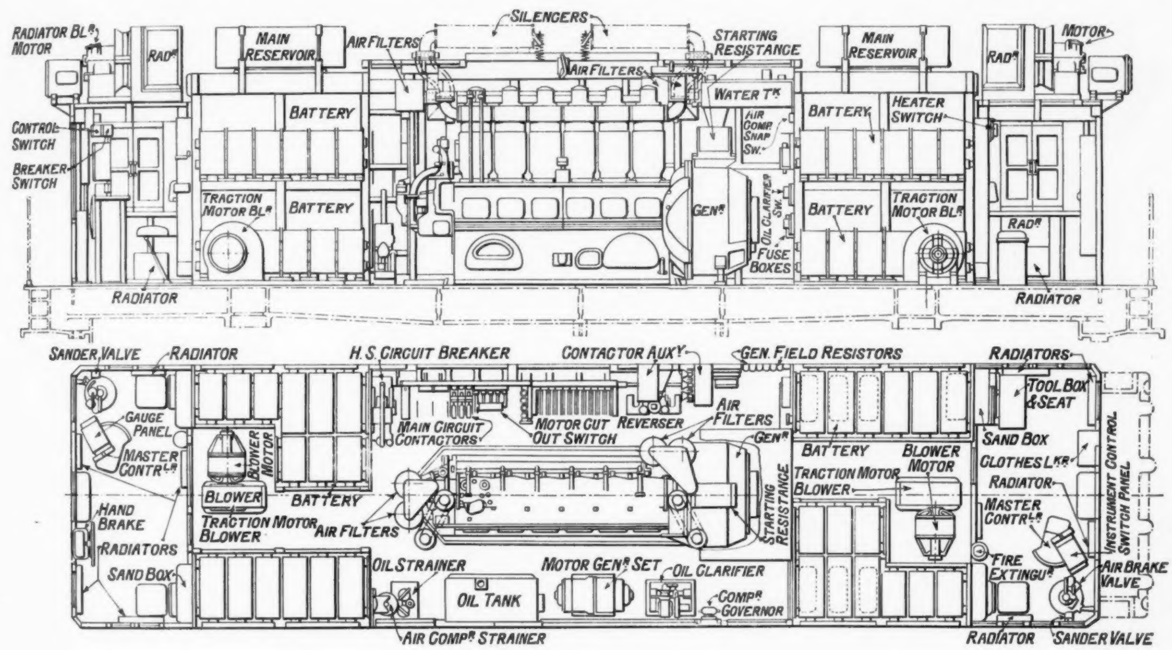
After putting into service in 1928 a trial locomotive, the New York Central ordered a further 41 three-power machines, 35 of which were for use in New York, two for passenger shunting at La Salle Street station in Chicago, and four to be operated in Chicago by the associated Michigan Central Railroad. The general appearance of these locomotives is shown in the illustration appearing at the head of this article, and in the accompanying layout drawing.

Diesel motive power is provided by one of the Ingersoll-Rand standard 300 b.h.p. engines, and the 240-cell 650 amp.-hr. storage battery is automatically charged from the engine-generator set when the locomotive demand is below normal engine power. In turn, the battery and engine together furnish power to the four traction motors when the demand is above the engine capacity. The wheel arrangement is of the Bo-Bo type, the bogies having a wheelbase of 8 ft. 3 in. and a centre to centre pitch of 25 ft. 10 in. The total weight of the locomotive is 114 tons, and this gives an adhesion factor of 4·0 against the maximum tractive effort of 64,000 lb. With forced ventilation, the tractive capacity of the motors is 33,800 lb. on the hourly rating, and 24,600 lb. continuously, and the tractive effort range compared with steam and electric locomotives is indicated in Fig. 1. The control is of the electro-pneumatic non-automatic type, and gives six motor combinations, three on internal and three on external power. Although the engine is of only 300 b.h.p., combined engine and battery outputs of 800 b.h.p. are possible for short periods, and the capacity on external power is 1,600 h.p.

A box type cab is built up on the cast steel underframe shown suspended from a crane in one of the accompanying illustrations. Welding has been largely used in the fabrication of the cab, and this method of construction, in conjunction with one-piece castings such as the truck frame assembly and underframe, has enabled riveting to be almost eliminated.

The trucks are of the usual American pattern with side equalising springs, but quiver springs are provided on top of the axleboxes to improve the riding qualities. The pedestal construction is such that by dropping the tie-bar the pedestal shoes may be dropped, permitting the boxes to be pulled outwards, which, in turn, allows the wheels and axles to be removed without disturbing the motors, except to remove the axle-bearing caps, the motor being supported on a bracket secured to the locomotive underframe.

All the N.Y.C. locomotives are alike, except that the six units at work in Chicago are not fitted with third rail shoes, although provision has been made for their future incorporation.



Layout of equipment, New York Central three-power locomotive

Operating Statistics

The following operating statistics are based on the performance of the 36 DEs locomotives in service in and around New York City and are mainly based on performance for the year 1932.

TABLE I—UTILISATION AND AVAILABILITY—YEARLY BASIS

Year	Per cent. of total time available for service	Per cent. of time available actually at work	Per cent. of total time actually at work	Eight-hour tricks worked per day available
1931 ..	85·5	71·4	61·0	2·14
1932 ..	84·8	72·4	61·4	2·17
1933 (1st 9 mos.)	83·7	72·0	60·3	2·16

In order to show how the work of these locomotives is distributed between the different classes of service they are

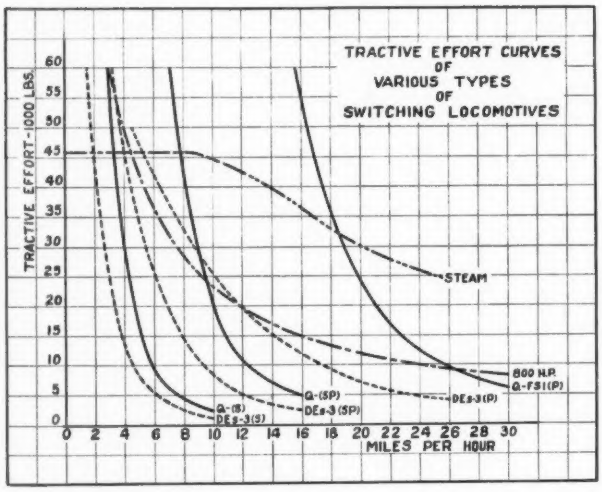


Fig. 1

used in, their distribution was carefully studied for a week in 1933 and the results given in Table II were obtained.

TABLE II—DISTRIBUTION OF TOTAL TIME

	Assigned	Actually at work	Idle and inspection
Per cent. of time in West Side switching service	51·3	42·0	9·3*
Per cent. of time in Electric Divn. switching service . .	11·6	6·6	5·0*
Per cent. of time in road service	23·7	8·3	15·4*
I.C.C. inspection, general shopping	13·4	—	13·4
	100·0	56·9	43·1

* Time for daily inspection included here.

During this week the average tricks worked per day available for all locomotives in all services was 2·09, which compares with the 2·14 and 2·17 found on the yearly basis, which indicates that the period selected was quite representative of the yearly average performance.

Based on the total number of locomotives, the assignments would be approximately as follow:—

West Side switching service	19
Electric division switching service	4
Road service	8
I.C.C. inspection and general shopping	5
Total	36

The I.C.C. inspection has to be made once each month and requires about a day, so that one or two locomotives are always out of service for this.

The availability for the year 1932 is expressed graphically by Fig. 2, which shows the tricks worked, tricks not available (being tricks the locomotive was in the shop or being inspected), and the tricks available but not worked. (A trick consists of eight hours, there being three tricks in a 24-hour day. Not all tricks scheduled are of this length, but they have all been adjusted to bring them to the basis of eight hours.) The average actual miles a trick and the average miles per hour are shown by Fig. 3. These are computed from readings of odometers located on the locomotive axles, which are read at each I.C.C. inspection. This mileage should not be confused with the mileage which is reported to the I.C.C., and which for accounting purposes for switching locomotives is based on an arbitrary figure of 6 m.p.h. It will be noted that actual average speed is 3·2 m.p.h., and this agrees closely with experience in other switching work.

The oil engines on these locomotives, when running, run at constant speed, and a record is kept by means of counters of the revolutions made, from which the engine hours are calculated, assuming an average speed of 560 r.p.m. Fig. 4 shows the average engine hours per month and average engine hours per trick for all locomotives. It will be noted that the average engine hours per trick is 3·6 which means the engine is running about half the time that the locomotive is in service. In switching service on the West Side, where there is no third rail, the engine is running practically all the time, but of course is shut down most of the time when the locomotive is running on third rail. The relative time between operation on third rail and off third rail is very difficult to determine, and no records of this proportion are available.

Cost of Maintenance

While the actual figures on maintenance vary so much between different roads and services as to make them of

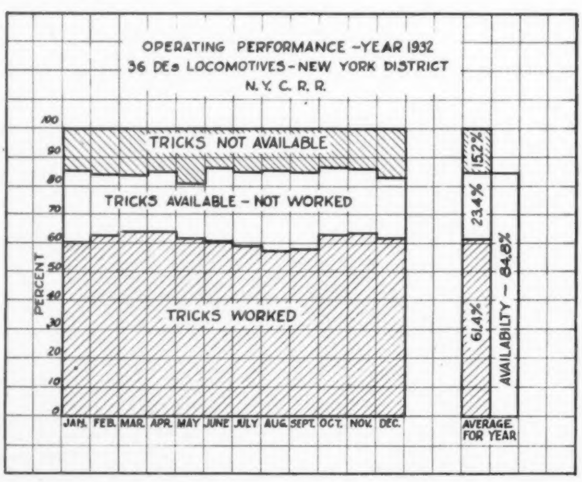


Fig. 2

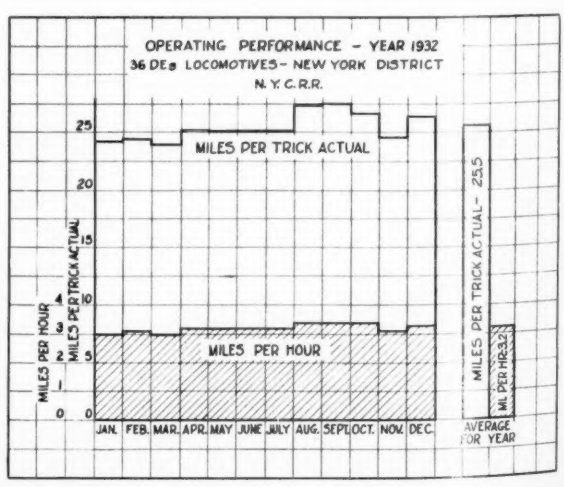


Fig. 3

little use for comparative purposes, at the same time the distribution of maintenance expenses between the different parts of the locomotives is of considerable interest and is shown by the following:—

	Per cent. of total
Mechanical—	
Brake and compressor	13·0
Body, painting, drawgear	10·3
Trucks	14·8
Electrical—	
Traction motors	9·2
Control	9·1
Current collectors	7·2
Storage batteries	4·6
Main generator	4·1
Diesel engine equipment—	
Engine radiators, radiator blowers, &c.	26·3
Miscellaneous	1·4
Total maintenance	100·0

The above costs do not include depreciation, which is

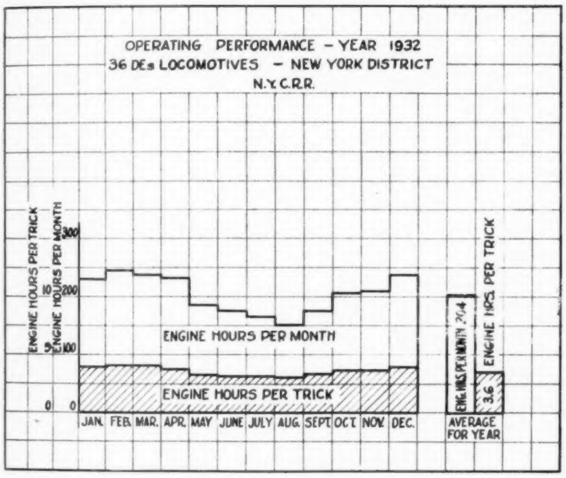


Fig. 4

distributed in the proportions indicated in the table given below:—

	Per cent.	Life on which depreciation is based
Storage battery	35·7	4 years
Oil engine	17·1	15 ,,
Balance of locomotive	47·2	28·5 ,,
Total depreciation	100·0	

The total depreciation is about 170 per cent. of the total maintenance.

General Comments on Design and Operation

These locomotives are known as the three-power type because they are capable of operating, on the N.Y.C., from either third rail at 600 volts; engine and battery together; or battery only. When operating from third rail they have the characteristics of series, series-parallel and parallel of the class "Q" locomotives shown on Fig. 1. When operating on internal power (engine and battery) they have the three running positions shown by DEs3, (S), (SP) and (P). Rheostatic steps are used in between these positions.

When not operating on third rail it is intended that they should be operated from the engine and battery with the engine running practically all the time that the locomotive is in service. There are, however, certain services into warehouses and other locations on the West Side where operating of the diesel engine is not permitted inside of the buildings and where operation on the battery only is used. This, of course, is at speeds somewhat lower than those shown in Fig. 1.

There has been at times considerable discussion as to what work this type of locomotive will actually do, and for what classes of service it is best suited. The first N.Y.C. locomotive was provided with a number of instruments and meters and a great deal of data was secured, and on this material the following remarks are largely based.

The three-power locomotive is best suited for switching service where the power is not on continuously, and especially when used in conjunction with power supply from third rail or trolley. It has the characteristic on internal power of being able to supply instantly large amounts of power for short periods of time, as is required when kicking cars. It is not well suited for long runs with

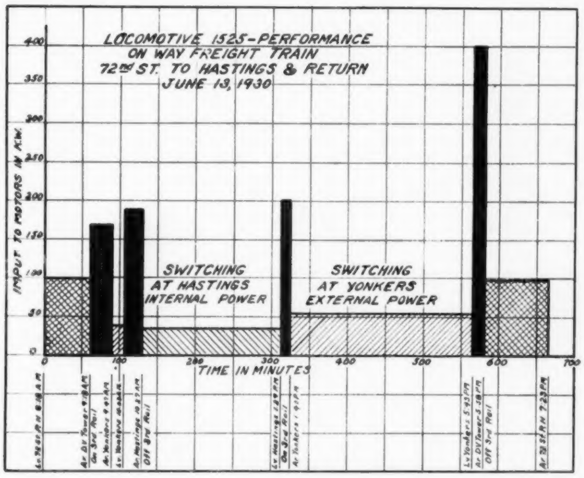


Fig. 5

rated load on internal power only, as these discharge the battery considerably and high battery temperatures are caused by the heavy recharging necessary. This type of locomotive has been used on continuous runs of 8 to 13 miles on internal power, but it is not working to best advantage when used on continuous runs of more than two or three miles. For long runs the external power should be available.

For road freight and travelling switcher service, where operation is partly from external and partly from internal power, they are in their element, and permit this service to be very economically handled, as the cost of electrification of the sidings and industry tracks can be saved. In the case of industrial plants along the right-of-way this is an important item, not only due to the cost involved, but also the physical difficulties in connection with electrifying many of these tracks.

Fig. 5 shows the observed performance of the first N.Y.C. locomotive on a road freight train for a distance of about 16 miles and return. The train handled weighed about 1,000 tons, approximately half the tonnage rating of the locomotive. First comes a road run on internal power for about eight miles, then a road run on external power for eight miles, with a short period of switching on external power, then switching on internal power, then a short run on external power, switching on external power, a short road run on external power and, finally,

a road run on internal power back to the starting terminal. Incidentally, it was then the practice to work the locomotive a shift in float service at night and send it out on the road freight the next day. From the time the second batch of oil-electric-battery locomotives went into service in August, 1930, until June, 1931, they handled 1,800-ton trains in regular service from 72nd Street to Spuyten Duyvil on internal power, and thence on external power. With a train of this weight the power required is about double that shown in Fig. 5.

It should be noted that only about 50 kWh. per hour input to the motors is required for switching service even on external power. 50 to 60 kWh. per hour input to motors has been found to cover the average requirements of switching service, but it has also been found that peaks of 600-800 kW. are used momentarily, especially when rapid acceleration is required, as when kicking cars.

The characteristics of this type of locomotive, both on internal and external power, are shown by Fig. 1. This figure shows a comparison of the tractive effort curves of a 100-ton steam switcher, an 89-ton straight electric switcher (Q), the three-power locomotive on internal power (DEs-3), and a straight oil-electric locomotive with an 800 b.h.p. engine. The characteristics of the DEs-3 locomotive on external power are the same as the Q locomotive. It will be noted that on internal power the DEs-3 locomotive has more tractive effort available at the same speed than an 800 b.h.p. oil-electric up to about 12 m.p.h., where the curves cross, the 800 b.h.p. locomotive having more tractive effort at higher speeds. On external power the tractive efforts available are much beyond the 800 b.h.p. locomotive for speeds from 5 to 20 m.p.h.

When operating entirely on internal power, the capacity of the battery and the size of the oil engine limit the work that can be done by the locomotive. There has been a great deal of misunderstanding concerning the duty on the battery for a given amount of work done by the locomotive. Fig. 6 shows in graphical form some results obtained from the first locomotive in float service. The first group shows the distribution of kWh. for an average trick. It will be noted that the input to the traction motors was 440 kWh. or an average of 55 kWh. per hour. The battery furnished, by discharging, 80 kWh. or 18 per cent. The battery losses in recharging were 24 kWh. or 5·5 per cent. It will be noted that the total generator output was 550 kWh., making the electrical efficiency of the locomotive 80 per cent.

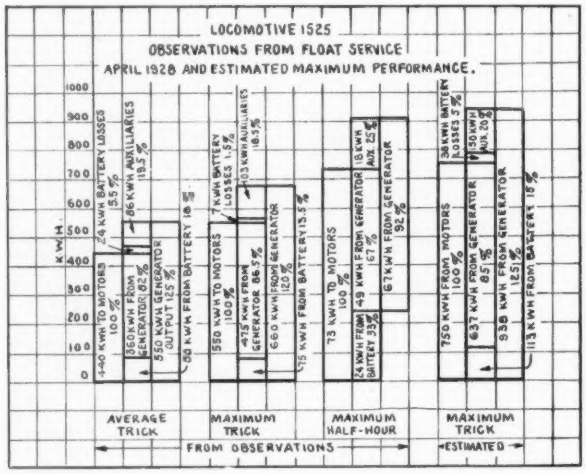


Fig 6

The next group shows the conditions on the maximum observed trick (based on motor kWh. input). Here the motor input increased to 550 kWh. or 69 kWh. per hour, but the battery discharge fell off to 74 kWh. and battery losses to 7 kWh. Electrical efficiency increased to 83 per cent. The third group shows conditions for the maximum half hour observed. Here the motor input was 73 kWh., or at the rate of 146 kWh. per hour, about three times the rate for the average trick. The battery furnished 24 kWh. in this time, or at the rate of 48 kWh. per hour. This is 33 per cent. of the motor input, and corresponds to 105 per cent. of the six-hour discharge rate. The generator furnished only 67 kWh. or 92 per cent. of the motor input.

The fourth group shows the estimated maximum trick that this locomotive can perform. This shows a motor input of 750 kWh., or at the rate of 94 kWh. per hour. Battery discharge is 113 kWh. or 15 per cent. Battery losses are 38 kWh. or 5 per cent. This is based on the locomotive being in three-trick service, and with a total battery discharge for 24 hours of 125 per cent. of the rated six-hour capacity, which is the limit, due to permissible temperature rise. It may be remarked in passing that the first locomotive actually worked one trick in another service with this input to the traction motors, but only 890 kWh. output was required from the generator, as compared with the 938 kWh. estimated.

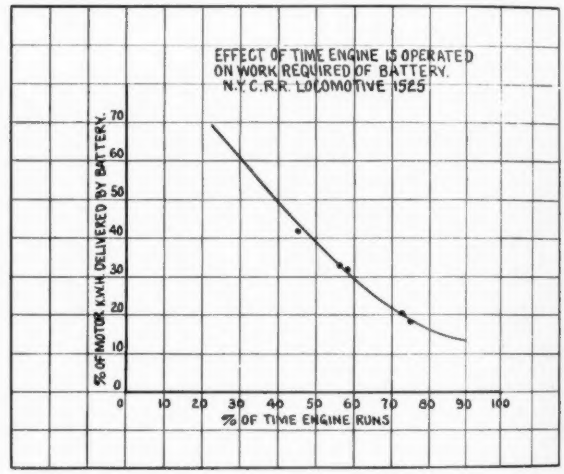


Fig. 7

Particular attention should be paid to the relatively small amount of work done by the battery. Most of the energy is delivered directly from the generator to the motors. The peak demands in switching service, while high, are only of short duration, and while very important in securing prompt and rapid movement of the cars do not represent many kWh. in a trick of eight hours. There is a popular misconception of these locomotives which has the battery furnishing practically all the motor kWh. and then being completely recharged from the generator. As can be seen, this condition does not occur in practice.

Fig. 7 has been prepared to further illustrate the same point, and is based on data taken from the original locomotive. It will be noted that as the engine is operated a greater percentage of the time, the percentage of the motor kWh. delivered by the battery is reduced until a minimum of about 15 per cent. is reached. These tests indicated the desirability of operating the engine practically all the time the locomotive is in use with the exception of periods when standing idle or when certain

moves have to be made on battery alone, and this is the practice followed on the N.Y.C. locomotives. Light engine moves are usually made on battery with engine shut down.

The average load on the generator, based on the time it is running, is usually about **40** per cent. of its rated load on average tricks, and about **70** per cent. on maximum tricks. The instantaneous load varies from about **10** to **100** per cent., and the fuel is limited beyond this point to prevent overloading the engine. The fuel consumption of the engines is good, as these high average loads bring the load into the part of the fuel consumption curve where the engine operates near best economy. This feature makes the overall fuel economy as good as, or better than, a locomotive with larger engine horsepower and no battery, doing the same work, which would necessarily operate at a considerably lower load factor. The DEs-3 locomotives averaged **35** U.S. gallons per trick or **9·7** gallons per engine-hour for the year **1932**. When operating on internal power all the time they use from **65** to **75** U.S. gallons per trick.

Table III gives some simple rules by which the size of engine and battery can be determined for a given work required, as well as showing the size actually used on the N.Y.C. three-power locomotives. These figures are based on average and maximum motor input kWh. per hour which were determined from tests made on the first locomotive in various classes of switching service. Only a class of service that combines transfer or the breaking up of very heavy trains will exceed the figures given in this table.

72nd Street yards, New York Central Railroad. Shunting operations in this yard along with others in New York City are performed by oil-electric-battery locomotives. Photograph taken in the old steam days

TABLE III—RULES FOR PROPORTIONING THREE-POWER LOCOMOTIVES

	Average	Maximum
Motor input, kWh. per 8-hr. trick	480	800
„ „ kWh. per hour ..	60	100
Efficiency of locomotive, per cent.	80	80
Generator output ; kWh. per hour/efficiency, kW.	75	138
Assumed load factor, per cent. ..	40	70
Generator rating, kW.	187	197
Battery duty, 15 per cent. of motor ; kWh./hr.	9	15
Battery capacity for 24-hr. service. $\frac{\text{kWh./hr.} \times 8 \times 3}{1\cdot25}$ kWh.	173	288
Battery amp. hr. capacity. kWh./cells × 1·95 (Assume 218 cells) Amp. hr. ..	406	678
Actual Ratings :	Original loco.	DEs-3 loco.
Generator, continuous, kW. ..	200	200
Battery—6-hr. rating ..	218 cells 294 kWh. 680 amp. hr.	240 cells 301 kWh. 650 amp. hr

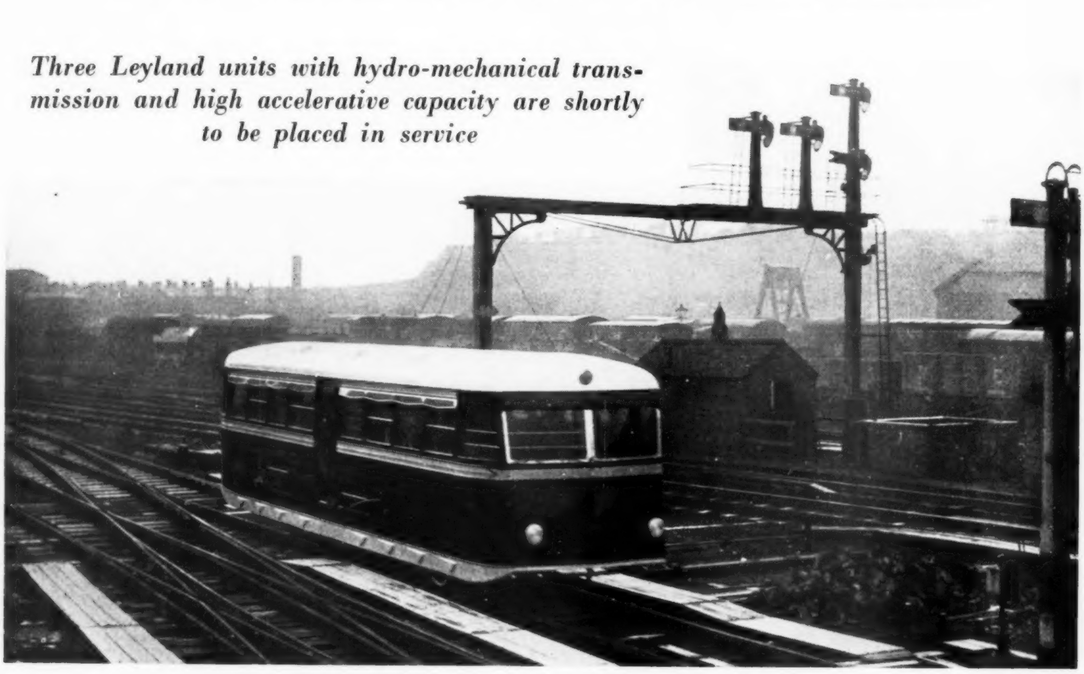
HIGH SPEED DIESEL TRAINS.—In the article "Possibilities of High Speed," published in the issue of this Supplement for January 26, the captions under Figs. 3 and 4 should have been transposed.

FRENCH LICENCE FOR GERMAN DIESEL LOCOMOTIVES.—The Deutsche-Werke, of Kiel, have just granted a licence for the construction of their diesel engines and locotractors to the Soc. des Ateliers de Construction du Nord, who have also, through the Deutsche-Werke, acquired a licence from the Triebwagenbau A.G., of Berlin.

RUSSIAN DIESEL-ELECTRIC PROPOSAL.—The Soviet authorities are proposing to commence the construction of a diesel-electric locomotive in which alternating current will be used in the transmission system.

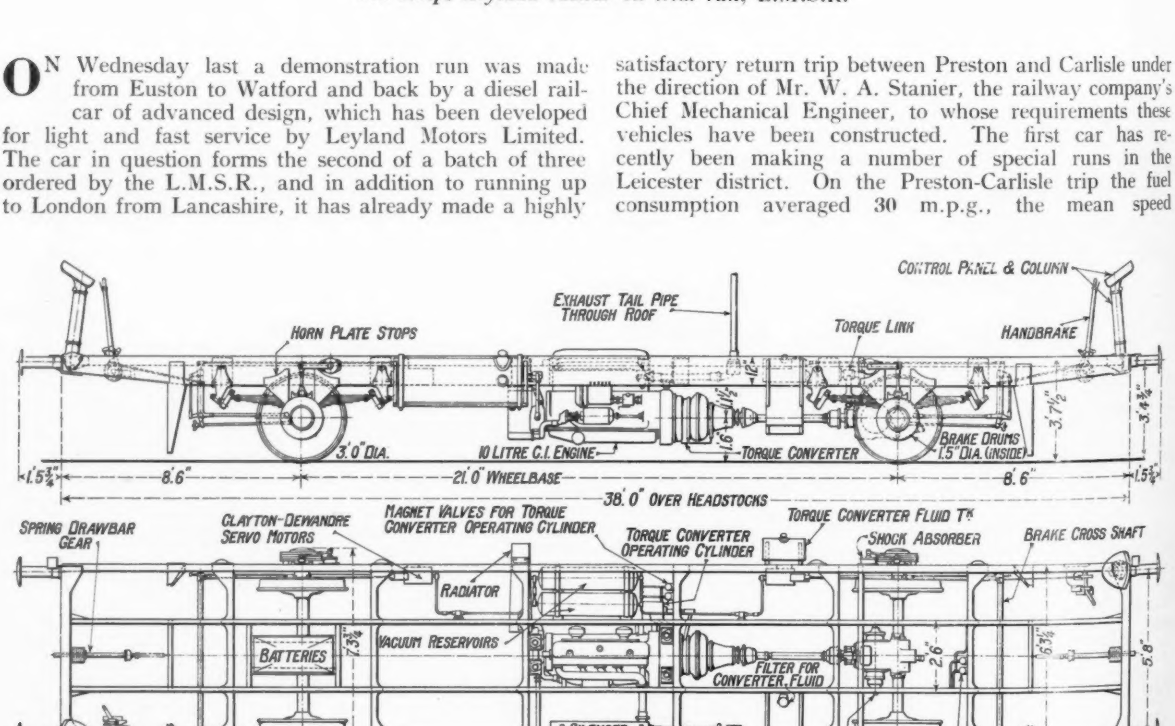
LIGHT DIESEL RAILCARS FOR THE L.M.S.R.

Three Leyland units with hydro-mechanical transmission and high accelerative capacity are shortly to be placed in service

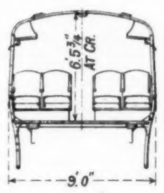


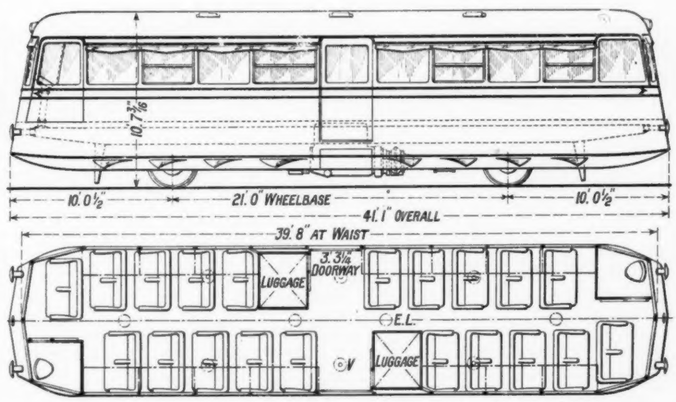
130 *b.h.p. Leyland railcar on trial run, L.M.S.R.*

On Wednesday last a demonstration run was made from Euston to Watford and back by a diesel railcar of advanced design, which has been developed for light and fast service by Leyland Motors Limited. The car in question forms the second of a batch of three ordered by the L.M.S.R., and in addition to running up to London from Lancashire, it has already made a highly satisfactory return trip between Preston and Carlisle under the direction of Mr. W. A. Stanier, the railway company's Chief Mechanical Engineer, to whose requirements these vehicles have been constructed. The first car has recently been making a number of special runs in the Leicester district. On the Preston-Carlisle trip the fuel consumption averaged 30 m.p.g., the mean speed



General arrangement of underframe and chassis, Leyland railcar





130 b.h.p. Leyland diesel hydro-mechanical railcar

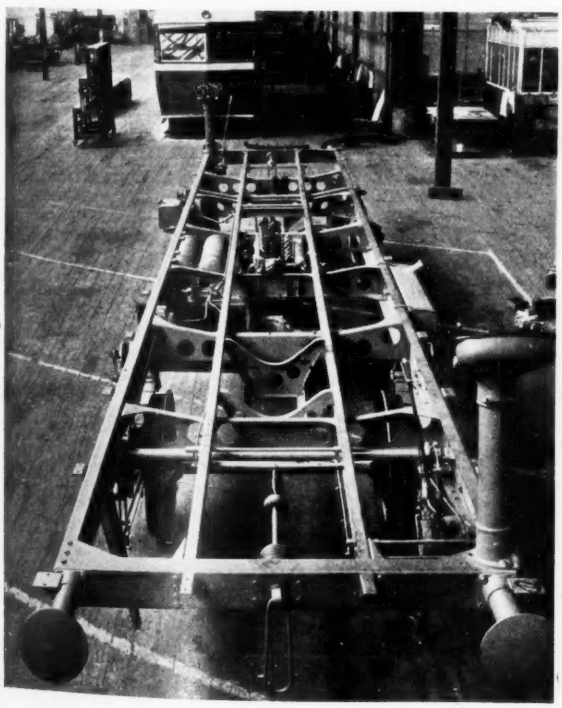
was in the neighbourhood of 50 m.p.h. and the hill climbing over Shap remarkable.

The car is noteworthy in taring only 10½ tons for a seating capacity of 40, and being powered by a 130 b.h.p. six-cylinder Leyland oil engine, the capacity of 10 b.h.p. per ton in the loaded condition enables exceptionally high rates of acceleration to be attained. Indeed, rates of approximately 3·25 ft. per sec. per sec. have been recorded, and this without undue discomfort to the passengers, thanks to the smooth operation of the hydraulic torque converter. Speeds of 20, 30, 40 and 50 m.p.h. are normally attained in 11, 20, 32, and 49 sec. respectively from a standing start. The maximum speed of the cars is limited at the moment to 56 m.p.h. but the ample power available enables this speed to be maintained up normal grades. The car is not designed for the haulage of trailers, and only simple and light buffing gear is fitted.

The four 36-inch wheels are carried in a manner that savours of road practice, as may be seen from the chassis drawing and two of the accompanying illustrations. The axles are carried in Timken roller bearings which are located outside the wheels and inside 17-inch brake drums mounted on the axle ends. Both vacuum and handbrakes are incorporated, but instead of applying blocks on the wheel treads they operate internal-expanding fabric-lined shoes working in the above-mentioned drums, which are well-cooled by the movement of the car. The hand brake is of a double-ratchet pattern developed on the Leyland road vehicles. The vacuum brakes are applied by Clayton-Dewandre servo-motors, which are secured to the underframe between the wheels and the radiator for the torque-converter fluid.

Laminated springs are used in the suspension, one end of each spring being secured to a universal joint and the other being allowed to move longitudinally. This arrangement allows the axle to follow curves, and gives a restrained lateral movement to cushion any shocks received by the wheel flange. Some such arrangement is obviously necessary in view of the long wheelbase of 21 ft. Horn plate stops dropped from the underframe limit the longitudinal movement of the axle, but are not normally a constraining factor.

An all-steel underframe of light and elegant design has been built up by welding, the main members being 12-in. by 3-in. by ¼-in. channel sections. On this is mounted an all-steel body, and here again, welding has been largely used. With the exception of such auxiliaries as the battery, the complete car has been constructed at the Leyland works. The principal dimensions may be culled



Welded underframe

Control dashboard and pillar

Interior of Leyland railcar

from the diagram which we reproduce on page 325, and from the chassis drawing on page 324.

Although the suspension gear is unusual, the car ran very steadily, for a four-wheeled vehicle, on the occasion of the Euston-Watford demonstration, and although carrying more than 40 passengers ran for much of the distance at 50-53 m.p.h., and covered the 17½ miles from Euston to Watford in 24 min. 10 sec. The simplicity of the drive was strikingly demonstrated by the fact that the car was most efficiently driven back from Watford by a Director of the L.M.S.R.!

The Transmission

One of the principal features of the design is the incorporation of the Leyland torque converter, which, as the Lysholm-Smith transmission, was fully described in the issue of this Supplement dated November 3. As may be seen from the accompanying illustrations the torque converter is anything but bulky, and is bolted direct to the engine casing, the final drive to the axle being through a tubular cardan shaft fitted with Hardy-Spicer couplings to a double-reduction gear mounted on the centre of the axle. Spiral bevels are used for the first reduction and ground spur gears for the second. The spur pinion can be meshed with either of the two bevels by means of internal teeth, so as to provide reverse gear of the same ratio.

To ensure the removal of any air or vapour which may be liberated by the converter fluid during operation or when filling up, a small pipe is carried from the top of the converter casing to an ejector fitted in the reverse tank. Whenever the converter is running, fluid flows through the pipe to the ejector, the other entry of which is coupled to the drainage sump, and thus automatically returns any leakage past the seals to the reserve tank. The function of the reserve tank is, of course, to keep the converter full of fluid under all conditions of operation. In order to secure maximum efficiency, it is advantageous to maintain a minimum pressure in the casing of about 30 lb. per sq. in. and, therefore, fluid from the reserve tank is fed to the converter through an injector. This injector is worked by means of fluid short-circuited from two points in the converter which have an appreciable pressure difference. In order to limit the temperature rise in the working fluid, a small cooler is placed on the frame side and connected in parallel with the fluid circulation. The fluid used in the converter consists of a mixture of paraffin and 5 per cent. of light spindle oil or of ordinary fuel oil.

Reversing is controlled by magnet valves operated from a switch in the driving cabin, which control the vacuum on either side of a double-acting cylinder which moves the pinion from one bevel to another. As it is necessary for the car to be at rest before the direction of motion is changed, the control operating this is interlocked with the torque converter switch, which must be in the neutral position before the former can be moved. The gearing has a ratio of 4·016:1, is housed in an aluminium casing, and is pressure-lubricated. It is shown mounted on the axle in one of the illustrations presented with this article, and the layout of the transmission system as a whole may be seen in the accompanying chassis layout drawing.

Passenger Comfort

Many appreciative comments were passed, during the Watford demonstration run, on the comfort and arrangement of the seating, and, above all, to the clear look-out all round, especially at the ends. The heating, too, was very effective, and the general performance of the car was such that an increase in traffic may be anticipated should these vehicles be set to work on a normal branch line.

Brake drum ready for assembly

A SUCCESSFUL HYDRAULIC DRIVE

British firm acquires rights of system applied to over 30 railcars, and now being incorporated in the improved Flying Hamburgers

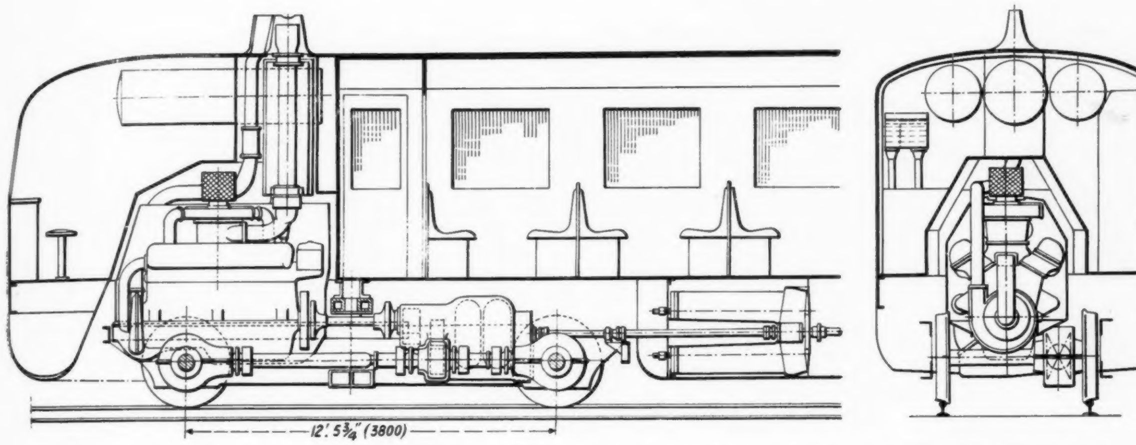


Fig. 1—Front end of new Flying Hamburger railcar showing 600 b.h.p. supercharged Maybach engine and Voith hydraulic turbo-converter

AS a result of the performances put up by the Flying Hamburger, the German State Railway last year ordered two further vehicles, one of which was intended to run in conjunction with the original unit, and the other to operate on various other services. In the meantime, experiments made by the Maybach Motorenbau had shown that by supercharging it was possible to increase considerably the output of their 12-cylinder V-type 410 b.h.p. engine, and the engines fitted to the latest cars are provided with a turbo-supercharger which enables an output of 600 b.h.p. to be continuously maintained without increasing the former speed of 1,400 r.p.m. The weight of the engine with supercharger is 5,300 lb., or 8·85 lb. per b.h.p., compared with the 9·25 lb. per b.h.p. of the 410 b.h.p. unit.

Hydraulic Transmission

The main point of difference, however, between the Flying Hamburger and the new cars is that electric transmission has been given up in favour of the Voith turbo-hydraulic drive, which has shown excellent performance on over 60 Austro-Daimler petrol-railcars, working mostly in Austria and Poland. The arrangement of the drive of the two 1,200 b.h.p. cars is shown in Fig. 1. This system has been developed and is constructed by the J. M. Voith Maschinenfabrik, of Heidenheim, Germany, and we are able to make the exclusive announcement that the manufacturing and selling rights for the British Empire have just been acquired by the Hydraulic Coupling & Engineering Co. Ltd., of Isleworth, and the units installed under this agreement will be known as Voith-Sinclair turbo-converters. We understand that, conversely, the J. M. Voith Maschinenfabrik has acquired the German and Austrian rights of the Vulcan-Sinclair hydraulic coupling, described in THE RAILWAY GAZETTE for March 25, 1932, which is now well known in a wide range of traction and industrial applications.

It was with a view to meeting the demand for a light and economical infinitely-variable transmission gear that the Voith turbo-converter was developed for railway work. It is claimed that the flexibility is equal to that of electric transmission, and as with that drive, the speed of the driving axle varies automatically to correspond with the load imposed by the train weight and the gradient. Up to two-thirds of the maximum road speed, the efficiency of the Voith-Sinclair turbo-converter corresponds generally to that of electric transmission, but above that speed the drive is direct, and the efficiency rises to a maximum of 98·5 per cent. The weight is lighter than that of electric transmission, and in service the reliability has been proved to be of a high order, which is understandable in view of the fact that with the exception of the ball and roller bearings there are no parts in mechanical contact. As may be

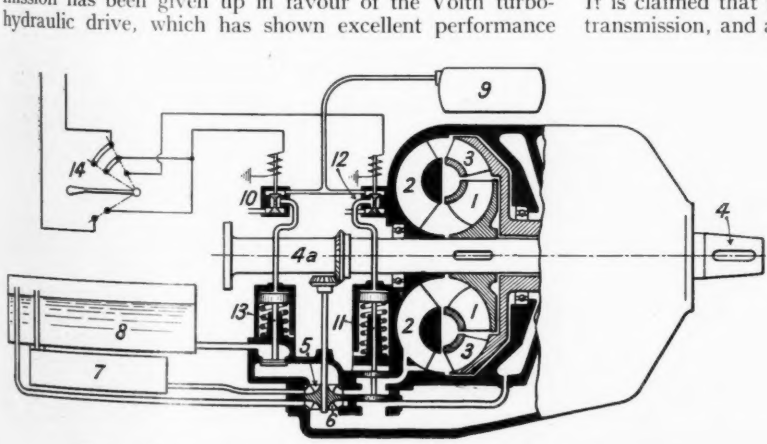


Fig. 2—Diagrammatic layout of Voith-Sinclair turbo-converter

seen from the accompanying drawing, the Voith-Sinclair turbo-converter consists of two separate elements: the converter, for use at starting and climbing; and the coupling, for working on the level and on slight grades.

The converter, or primary portion, **1**, in Fig. 2, converts the engine torque into the higher torque required by the driven shaft when running at reduced speed. The coupling, or secondary portion, **3** connects the engine directly with the final shaft, **4**, but with both connections the power is transmitted by the kinetic energy of the liquid circulating between the primary and secondary members. When both the working circuits are empty, the engine and driving axle are disconnected, and coasting takes place without the addition of any mechanical device, the liquid during this period being stored in the oil tank, **8**.

A small centrifugal pump, **6**, in the converter sump, and driven from the primary shaft, **4*a***, delivers the liquid to a control valve, **11**, which feeds it either to the converter or the coupling. From both units the liquid can drain off to the sump, so that they empty as the control valve is operated to stop the feed. A second set of impeller blading, **5**, on the pump returns the liquid from the sump to the tank, and the cooler, **7**, is located in the return pipe line.

Changing over from the converter to the coupling can be effected either automatically or at the will of the driver. In the latter case the actual change-over operation is carried out by electric remote control, **14**, which may easily be arranged from a cab on another railcar, and multiple-unit operation is thus quite practicable with the Voith-Sinclair turbo-converter. Any number of engines on the same train can be engaged or disconnected during running in any sequence, and the majority of vehicles now in working with Voith drive have two engines running in parallel. As only two definite end positions of the control-valve are required, the electric control is very simple.

The driving cab contains the engine throttle or fuel control, which is independent of the turbo-converter, and also the control switch which, with electrical control of forward and reverse gears, engages the desired direction gear, and the converter or coupling. Fast driving being necessary only in the respective forward direction of each driver's cab, the converter alone is connected with the reverse gear when the control is set to "reverse." In the neutral position, a stop valve, **13**, between the tank and feed pump is closed, so that both working circuits are emptied for coasting. The control is worked by electro-pneumatic valves, **10** and **12**, fed from the reservoir, **9**. A detailed arrangement of the Voith-Sinclair turbo-converter, as applied to a railcar powered by a **90** b.h.p. petrol engine, is shown in Fig. 3, the application in question consisting of two engines and two transmission systems connected in parallel.

Characteristics of the Turbo-Converter

In Fig. 4 the torque and efficiency curves are plotted on the basis of the speed of the secondary shaft. If, when driving through the converter, the engine speed is reduced, the secondary speed is thereby decreased in the same proportion, and the primary and secondary torques will decrease with the square of the speed, the efficiency remaining constant. When driving through the coupling, the secondary torque is, of course, equal to that of the engine. As the torque of internal-combustion engines reaches its maximum value at about half the normal maximum speed, the rising torque characteristic is felt when the engine speed is brought down due to changing over from the converter to the coupling while the road speed is about two-thirds of the maximum. The secondary speed at which this changing over should be done is given by the point of intersection of the secondary torque curve of the converter, with the torque curve of the coupling. It will be seen that when driving through the coupling at above two-thirds of full speed the transmission efficiency rises to almost the **100** per cent. value.

With light railcars on generally level lines, about **90** per cent. of the mileage is covered with the direct drive

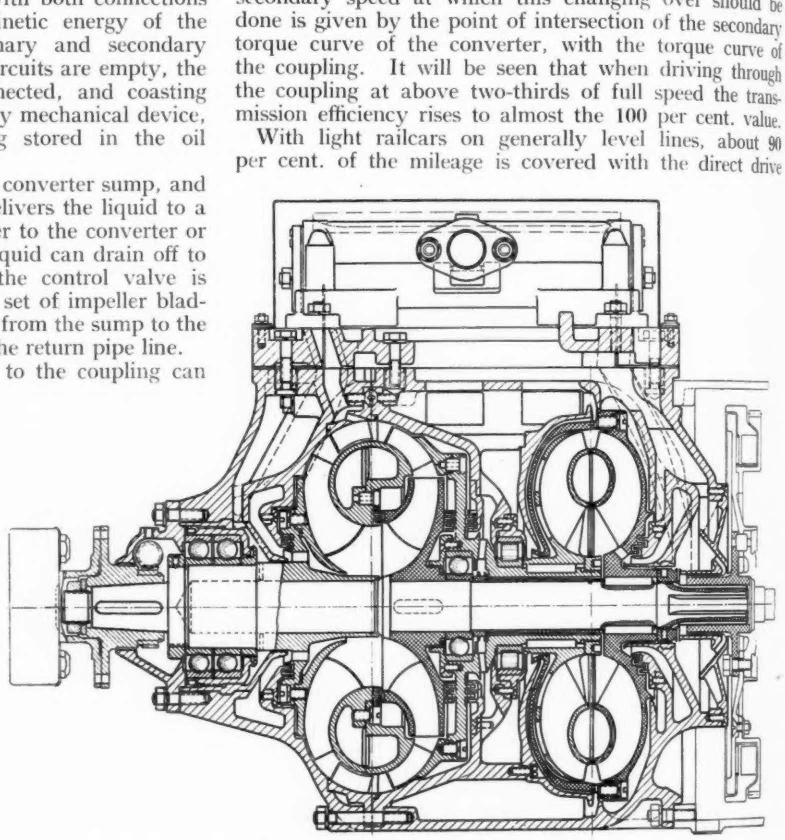


Fig. 3—General arrangement of Voith-Sinclair turbo-converter as used in conjunction with **90** *b.h.p. engine*

in operation, and the time during which the turbo-converter is in service at the higher torque multiplications is short. Taking an average efficiency of **97** per cent. for the coupling and **80** per cent. for the turbo-converter, the mean efficiency of the drive throughout an average run will be **95·3** per cent. It is on this account that only a very small cooler is provided, and that the turbo-converter has given such good results where the older form of full hydraulic transmission have failed.

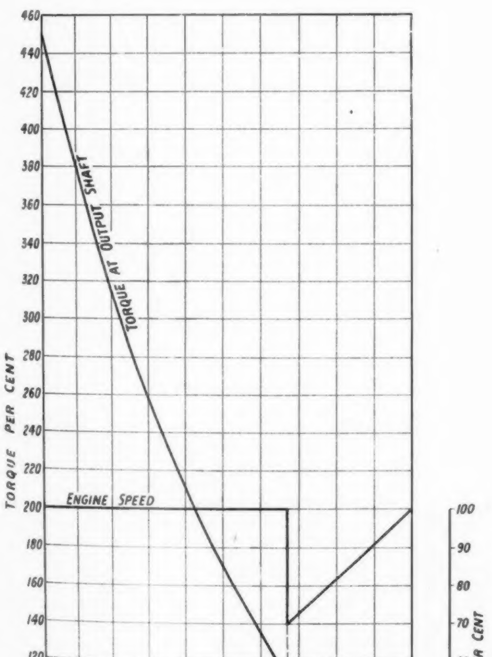
Driving Operations

After starting the engine and setting it to idling speed, the transmission control switch is moved from the neutral to the converter position, and as soon as the brakes are released the vehicle starts and accelerates in proportion to the opening of the engine fuel valve, and the resultant speed of the engine. On attaining about two-thirds of the top speed, the control switch is passed to "coupling," the fuel control remaining unchanged. No danger or difficulty is caused by changing over at a speed differing from the theoretically correct one, and, of course, the car can be propelled at reduced power and speed through the

turbo-coupling. When starting on a grade upon which an advantageous change-over speed cannot be reached, the turbo-converter is used until the grade is passed, and, *vice-versa,* when driving through the coupling and a heavy grade is reached which slows down the car, the turbo-converter may be switched in without throttling the fuel.

With those engines in which each position of the fuel control corresponds to a definite engine speed, the speed of the vehicle when driving through the coupling can be exactly adjusted by the position of the fuel lever as long as the motor can develop a power in excess of the resistance of the vehicle. Thus it is possible to drive through the coupling also at speeds below the change-over speed as long as with full fuel the motor is able to maintain the desired speed. This case often happens when approaching a stop signal. For speedy acceleration after the right of way has been given, the converter is used until the change-over speed is reached.

When driving through the converter the speed of the vehicle will automatically correspond to its resistance. There is thus not a definite relation between the road speed and the position of the fuel control, but in this case also the highest vehicle speed is naturally reached at the highest engine speed. When no power is required the control switch is brought to the neutral position and the fuel lever to idling. The vehicle will be disconnected from the engine, the turbo-converter acting thereby as a coasting device.



Torque and efficiency curves, Voith-Sinclair turbo-converter

From the coasting condition it is possible to pass, at will, to coupling or converter. The converter is switched in when passing from a falling grade to a rising grade, such that the change-over speed could not be reached by driving through the coupling. In all other cases it is possible to pass from coasting directly to coupling drive. Simultaneously with moving the switch to the coupling position the fuel control should be set for the desired speed of the vehicle, as otherwise the motor would be speeded up by the vehicle through the engagement of th coupling, and a momentary loss of vehicle speed would result.

When stopping with the converter in service, the switch is left in its position and the fuel control is set for idling. When stopping after coasting or with the coupling in service it is of advantage, when applying the brakes, to switch over to converter. Then, when re-starting, it is only necessary to release the brakes and admit fuel in order to obtain rapid acceleration.

Shunting

When the vehicle is stopped with idling engine, the control switch should be in neutral position. The switch may then be set to the converter position of the desired direction. If a reverse gear with jaw clutches is provided for, the latter may only be engaged at standstill of the vehicle in order to prevent damaging the jaws. If friction clutches are used, engaging can be done while running, but this leads to wear on the clutches.

For this reason it is recommended that vehicles which often change direction, such as shunting locomotives, should have one turbo-converter for each direction. Thus all mechanical reverse mechanisms are avoided and no harm can be done by false manœuvring. When the vehicle is running forward and the drive is suddenly reversed by filling the reverse turbo-converter, an intense braking effect is produced until the vehicle is stopped, and from that moment it accelerates with full power. Much time can thus be gained in shunting service where quick stopping and rapid acceleration is essential.

With regard to heat conditions the turbo-converter is more favourable than any other drive. Invariably, during starting, large quantities of energy must be absorbed and disposed of. In electric transmission this energy is dissipated as heat in the windings of the motors, whereas in mechanical transmission it heats the clutches; but in the hydraulic transmission the heat goes into the working liquid, which in partial hydraulic systems is easily cooled. For shunting locomotives it is only necessary to provide for a more ample cooling surface than is normal for railcar application, and there is no wear or any other inconvenience endangering the safety or reliability of the transmission.

Light-Weight Diesel Trains

Under the title of "Light-weight Motor Trains" an attractive brochure has just been issued by Armstrong-Whitworth & Co. (Engineers) Ltd., and announces the availability of a new range of diesel railcars and trains, which, it is claimed, will enable the railways to compete more successfully with road transport.

Illustrations and particulars are given of the 95 b.h.p. diesel-electric railbus now running on the L.N.E.R., and the articulated train built for the Sao Paulo Railway, and it appears that the new range has been based upon the experience gained in the construction and operation of these vehicles. Designs are reproduced of double-bogie cars, and of double and triple-articulated trains, the two last-named having respective seating capacities of 151 and 229.

A NEW TYPE OF FLUID CLUTCH

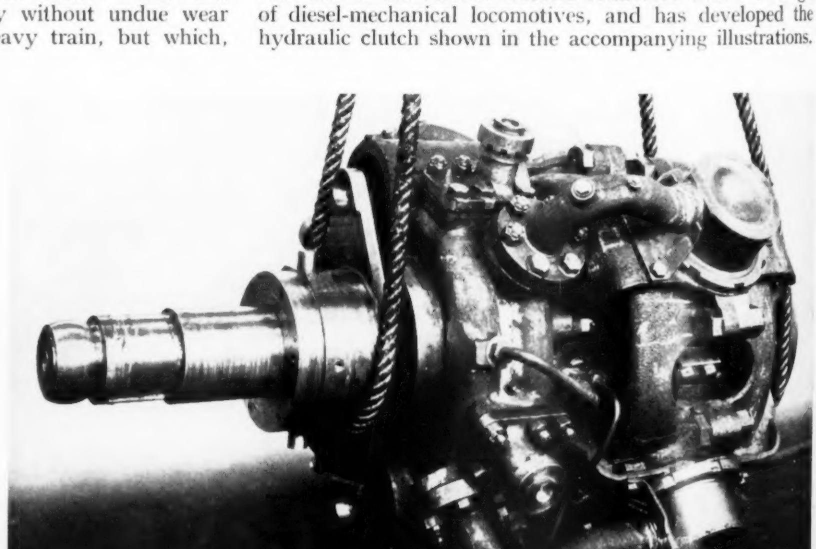
A German design which has given satisfactory results on high-powered diesel-mechanical locomotives

1,450 *b.h.p. diesel-mechanical locomotive with hydraulic clutch alongside* 2-10-2 *steam locomotive*

ONE of the principal problems connected with the application of gear transmission to diesel locomotives, whether of the heavy main-line or lighter duty type, is the provision of a form of main clutch which will have a sustained slipping capacity without undue wear or heating when accelerating a heavy train, but which, when necessity arises, will be capable of rapidly and smoothly taking up the full engine torque. The Lomonossoff **1,200** b.h.p. diesel - mechanical locomotive was originally provided with electromagnetic main and gearbox clutches, and although, for the time of construction, the results obtained were quite good, a certain amount of wear and heating took place, and the time for a complete gear change was **15** to **17** seconds, a period which could not be regarded as satisfactory for future units.

Since **1925**, when the Lomonossoff locomotive was completed, much progress has been made in clutch design, and hydraulic media are now in great favour, not only for high powers, but also for small locotractors which frequently have to develop their maximum tractive effort. The Lomonossoff locomotive itself has now been fitted with an hydraulic clutch of a type similar to that about to be described, and is now understood to be giving good service.

For some years the Fried. Krupp A.G. has given close attention to the various features connected with the design of diesel-mechanical locomotives, and has developed the hydraulic clutch shown in the accompanying illustrations.

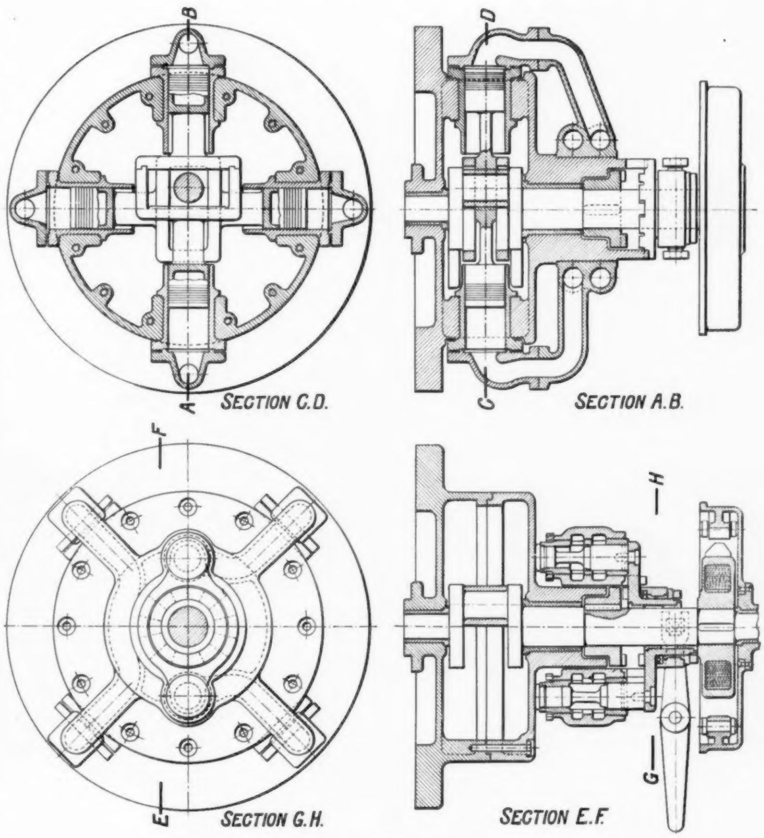


Hydraulic clutch as fitted to* 1,450 *b.h.p. locomotive

The unit shown in the half-tone is applied to the 1,450 b.h.p. locomotive built to the order of the Boston & Maine Railroad, but which for the past twelve months has been running on the German State Railway. The engine is supercharged, and runs at a normal speed of 470 r.p.m., the maximum tractive effort being 50,000 lb., and the road speeds 8·7, 16, 31, and 60 m.p.h. A similar design has been incorporated in the 600 b.h.p. 1-C-1 locomotive of the Japanese Government Railways, which was described in the issue of this Supplement dated December 1.

As may be seen from the sectional drawings presented herewith, the clutch consists essentially of a main casing with four cylinders arranged at right angles, the opposite pairs being connected by pipes, in which are located regulating valves. The casing also houses a jaw clutch and a spring coupling, and the four pistons are connected to a common crank pin. The main casing is rigidly secured to the main shaft of the diesel engine, and the crankshaft of the clutch is connected through the spring coupling to the primary shaft of the gearbox.

In normal operation the cylinder connecting pipes are filled with the working fluid. The regulating valves are operated by a lever which also controls the jaw clutch, the latter being arranged to take the drive directly when the clutch is fully in and transmitting the whole of the engine torque, thus relieving the load on the clutch, cylinders and pistons. In the "out" position of the clutch, the working fluid circulates through the interconnecting pipes, and there is no movement of the clutch countershaft. When the valves are closed, or partly closed, a resistance is opposed to the passage of the fluid, the amount of the resistance determining the slippage and torque transmission. Operating experience has proved that the capacity of the clutch can be evenly regulated from full open to full in without shocks.



General arrangement of Krupp hydraulic clutch

Railcars

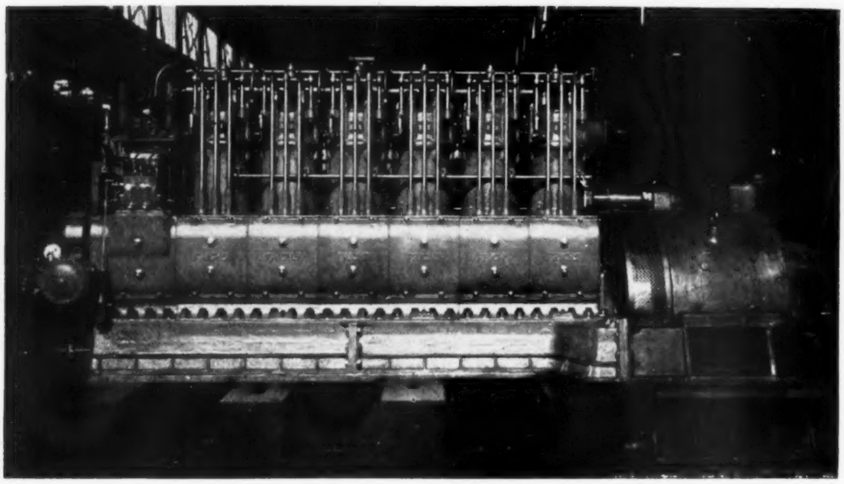
A PAPER, bearing the above title, was read by Mr. J. S. Tritton yesterday before the Institution of Locomotive Engineers. The author was pleased to note that the railways were now co-operating with railcar builders and refraining from demanding as in former years excessively strong and heavy components.

Experience showed that in the absence of the shock-absorbing pneumatic tyre automobile components required strengthening. For working a frequent service of cars stopping by request on branch lines, the author did, however, recommend a bus-like four wheeled vehicle seating 40 passengers, and having a power-weight ratio of 5 to 8 h.p. per ton. He strongly deprecated the policy of replacing such units by trailer sets working at less frequent intervals after traffic had been developed.

The advantages of the railcars were not to be made apparent by using them merely to work existing steam train services. On this plan there were lost two of the railcar's greatest advantages, namely, its increased availability and its capacity for accelerated schedules. When traffic increase necessitated a change, the service frequency should be increased, or, if block section working prohibited this, two power cars should be connected for unit working. Adding a trailer increased the power weight-ratio and adversely affected performance or necessitated the use of cars unnecessarily heavy and powerful for solo work. For extra high speed services a power weight-ratio of 25 to 30 h.p. per ton was used, but 8 to 10 h.p. was the rule for stopping services. The power weight-ratios for the A.E.C., Armstrong-Whitworth (2 cars) and Sentinel cars were 6·5, 5·35, 6·75 and 5 respectively. The Sentinel figure for short periods was 10. A comparison of over 40 British and Continental designs showed an average of 20 seats per axle, 3·2 seats per ton of tare and 8·2 h.p. per ton of tare. The question of transmission for diesel railcars was still unsettled, but in 1933, of 283 cars built, two-thirds had mechanical and one-third electrical transmission. The 75 to 80 per cent. efficiency of the latter and the 5 or so per cent. addition to the tare was against it, mechanical transmission having an efficiency of 85 to 88 per cent. on indirect drive, and 92-93 per cent. on top. Clutch difficulties were being overcome by the use of separate clutches for each gear (the bands of the Wilson gearbox were instanced) and the Vulcan Sinclair hydraulic coupling or "fluid flywheel." Above 35 m.p.h. wind resistance became important, and at 75 m.p.h. half the power needed to drive an ordinary car was expended against this. So far the use of rubber tyres had been restricted because no more than 36 cwt. could be carried on each wheel.

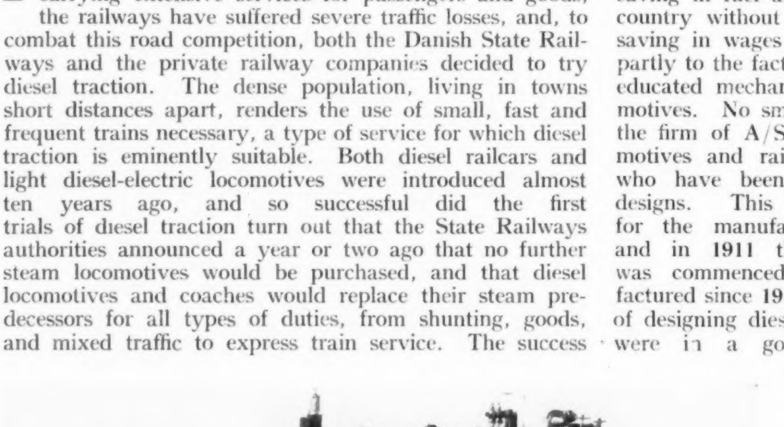
TEN YEARS OF RAILWAY DIESEL ENGINE BUILDING

Almost a hundred Frichs vehicles have been set to work during the past decade and are giving exceptionally reliable service



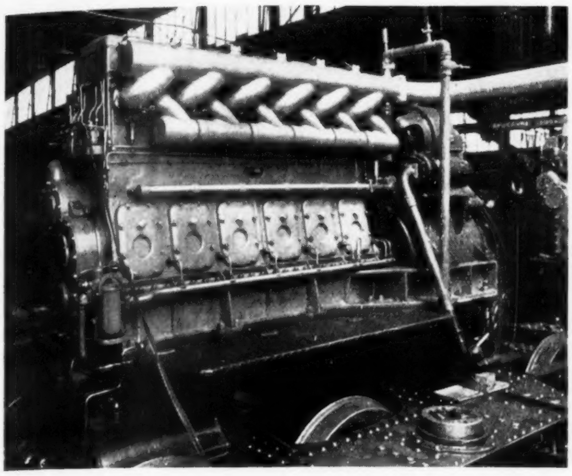
The first Frichs railway oil engine

IN Denmark, which has an excellent road system carrying extensive services for passengers and goods, the railways have suffered severe traffic losses, and, to combat this road competition, both the Danish State Railways and the private railway companies decided to try diesel traction. The dense population, living in towns short distances apart, renders the use of small, fast and frequent trains necessary, a type of service for which diesel traction is eminently suitable. Both diesel railcars and light diesel-electric locomotives were introduced almost ten years ago, and so successful did the first trials of diesel traction turn out that the State Railways authorities announced a year or two ago that no further steam locomotives would be purchased, and that diesel locomotives and coaches would replace their steam predecessors for all types of duties, from shunting, goods, and mixed traffic to express train service. The success of diesel traction in Denmark has been due partly to the saving in fuel and lubrication, of great importance in a country without natural power resources, partly to the saving in wages which has been found practicable, and partly to the fact that there are plenty of skilled and well-educated mechanics available as drivers for diesel locomotives. No small share of the credit must be given to the firm of A/S. Frichs, of Aarhus, whose diesel locomotives and railcars have been extensively used, and who have been largely responsible for the complete designs. This company was established in 1854 for the manufacture of steam engines and boilers, and in **1911** the construction of steam locomotives was commenced. Diesel engines have been manufactured since **1910**, and when, a decade ago, the question of designing diesel locomotives came to the fore, Frichs were in a good position to take up this new work.



Early power bogie as used on Frichs diesel-electric passenger locomotive

A vital factor in railway service is reliability, and another is that the engine must work automatically, and without attendance of any kind. Almost the first condition for obtaining this is that the diesel engine should be automatically pressure-lubricated throughout, and for these reasons a four-stroke engine was selected in preference to the two-stroke, and was used in conjunction with electric transmission. The engines of these early vehicles were all supplied with air injection, and were arranged for electrical remote control. The governor was not adapted for three-step control, and thus did not allow the driver to adjust the engine speed to the required load. It was not until **1929** that two-step control was introduced by Frichs, the first vehicles fitted being two **500** b.h.p. passenger locomotives for the Danish State



270 b.h.p. Frichs oil engine

Railways. Incidentally, these units were the first of Frichs build to be built up in the normal locomotive manner.

First Danish Locomotives

About ten years ago, the Frichs firm received its first order for a diesel-electric locomotive for a Danish private line. In the first of the accompanying illustrations is shown the diesel engine for this locomotive. It develops a rated output of 210 b.h.p. at 500 r.p.m., and although differing considerably from modern designs it has proved its reliability by covering 900,000 km. without any break-downs or troubles. Two more locomotives to the same design were delivered in 1926 to another Danish private railway, and, encouraged by the good results obtained, the Danish State Railways in 1927 ordered six of similar type, but with engines of 240 b.h.p.

Double-bogie diesel-electric railcars were then developed by Frichs, the normal design incorporating a diesel engine and generator mounted on one bogie in such a manner that the dynamo is entirely below the floor, thereby enabling the revenue-earning space in the car to be increased. The appearance of one of the early examples of this construction is shown in one of the accompanying illustrations. In addition to these six units for the Danish State Railways, another car of the same kind was delivered to a Danish private line during 1928.

Important Siamese Development

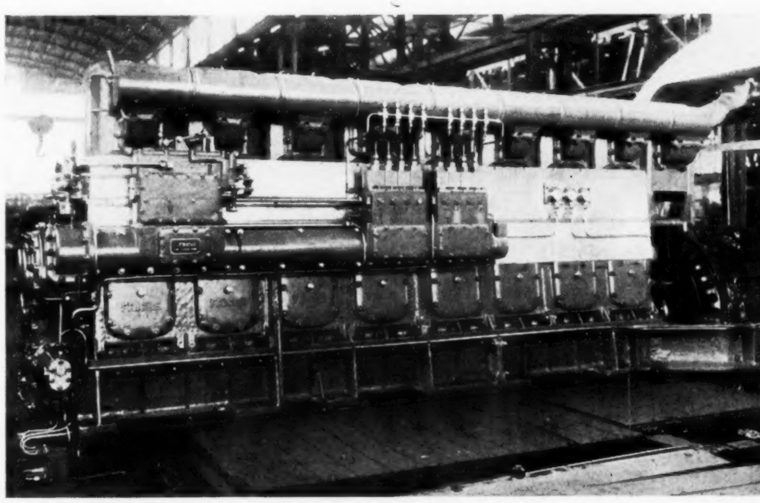
In 1930 the firm was entrusted with the execution of an important order for the Royal State Railways of Siam, consisting of six 1,000 b.h.p. express passenger locomotives, one 1,600 b.h.p. heavy freight locomotive, and six 180 b.h.p. railcars. The designing and construction of these units marked an important stage in the development of diesel traction, as, apart from their size, several improvements were embodied. The three-step electric control was introduced in connection with solid injection, and the lubricating oil pressure was utilised as the actuating medium in the servo-motor for the speed governor, thereby stopping the engine if the oil pressure should fail.

These vehicles being designed for use in a tropical climate, they could not be equipped with the ordinary roof coolers, but were supplied with side radiators with forced draught. The earliest roof coolers were of the same type as used for motor cars, but when the necessity for building more powerful units arose, it was necessary to develop a new type of tubular cooler. The latest type of roof radiator has the advantage that it does not project so far above the roof as the earlier patterns, and the appearance of the vehicle is thus improved, and the loading gauge utilised to best advantage.

Both the express passenger and heavy freight locomotives have double power plants, and one of the 800 b.h.p. engine-generator sets of the freight locomotive is shown in the last of the accompanying illustrations. A peculiarity of this engine, shared with other Frichs products, is that two camshafts are employed, one for the inlet and the other for the exhaust valves. Two fuel pump blocks are employed, and are driven from the main engine shaft.

Shortly after these vehicles were placed in service, the Danish State Railways ordered two 1,000 b.h.p. express passenger locomotives, which in the years 1931-33 were followed by a long line of locomotives, developing 300 to 450 b.h.p., supplied to various Danish private railways. A standard design, for use where train loads of moderate sizes are to be hauled in connection with a fast and frequent passenger service, was also developed by Frichs during this period. This series of locomotives demanded the standardisation of the diesel engines, in order that the same type should apply to all outputs, and as they differ to some extent from the older Frichs units, and are thoroughly up-to-date examples of the railway diesel engine, we shall describe them in some detail in a future article. It is, however, worthy of remark at this point, that the great majority of Frichs engines of both old and new designs, have gone into regular service immediately, and have given practically no trouble in maintenance.

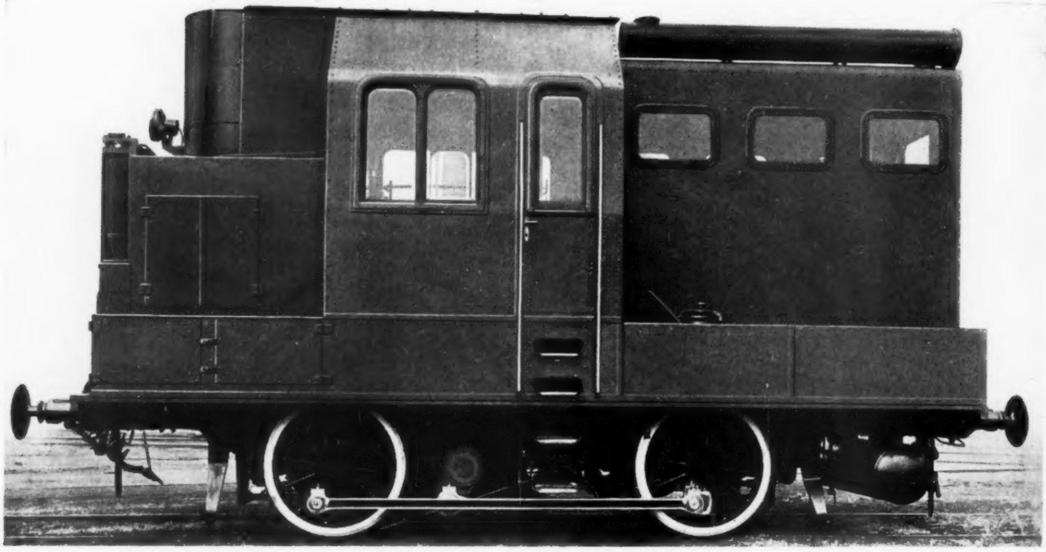
In addition to the agreement recently concluded between Frichs and the Vulcan Foundry, the Aarhus firm have granted licences for the manufacture of their railway diesel engines to Corpet, Louvet et Cie., for France, the Kockums Mekaniske Verkstad, for Sweden, and the Tammerfors Linne-och Jern-Manufaktur, for Finland.



Eight-cylinder 800 b.h.p. Frichs oil engine

HEAVY GEARED SHUNTING LOCOMOTIVE

German-built machine for Russia incorporates hydraulic clutch



300 *b.h.p. Russian diesel-mechanical shunting locomotive*

As a result of the experiments and studies made under the direction of Professor Lomonossoff in the years 1920-25, and under a technical committee thereafter, the Soviet authorities decided three or four years ago that electric transmission should not be considered for locomotives below 325 b.h.p., and in pursuance of this policy mechanical drive was adopted for the heavy four-wheeled diesel shunting locomotive recently supplied by Fried. Krupp A.G. for service on the Russian lines.

An M.A.N. light-weight high-speed oil engine provides the motive power, and develops 300 b.h.p. at 700 r.p.m. in six cylinders of 8·66 in. dia. by 12·6 in. stroke. This output may be temporarily increased to 390 b.h.p. at 850 r.p.m. The cooling-water pump and an air-compressor for the operation of the brake, sanding apparatus and gear clutches are driven from the engine, which is started by an electric motor with an automatic de-clutching arrangement. A 120-volt nickel-iron battery of 120 amp. hr. capacity provides current for starting, for the lighting circuit and for two electrically-driven oil pumps, and is charged through an automatic regulator from a generator having an output of 5·6 kW.

Cooling of the circulating water and lubricating oil is carried out on the usual Russian system, in which air is pulled through elliptical gilled radiator tubes and ejected upwards through a specially-shaped duct by means of a Betz fan. In this locomotive the fan is driven from the gearbox and can be operated at two different speeds, to suit the air temperature, by means of a change-speed gear provided with multiple-disc clutches. Effective cooling is obtained with ambient temperatures as high as 35 deg. Cent. For heating the cab and engine room, an exhaust-gas boiler is installed in the locomotive, and is started on wood or oil fuel.

The diesel engine torque is transmitted through a spring clutch to a four-speed gearbox. The road speed is changed by means of multiple-disc clutches actuated by pneumatic cylinders to which compressed air is led through fixed piping filled with labyrinth packing. The discs in one half of the coupling consist of steel plates having inserted plugs of a special friction material, whereas those in the other half are of wear-resisting steel. In order to avoid interrupting the tractive effort in changing over from one speed to another, the clutches controlling the two relevant speeds are operated in such a manner that one of them begins to engage before the other is completely disengaged, the control being by means of a rotary valve located in the driver's cab. In each gear-step the road speed can be varied to a certain extent by altering the engine speed, the road speeds at normal engine revs. being 4·35, 7·45, 13·25, and 22·7 m.p.h.

A bevel gear keyed to the prolongation of the engine crankshaft meshes continuously with two bevels mounted loosely on the first transverse gear shaft, and reversing is accomplished by coupling up alternately to these second bevels through multiple-disc clutches operated by oil under pressure, and controlled by a valve in the cab. The drive from the final gear shaft, or jackshaft, is taken through connecting rods to the wheels, and as will be seen from the accompanying illustration these are located *inside* the coupling rods. The principal particulars of the locomotive are as follow:—

Gauge	5 ft. 0 in.
Wheel dia...	4 ft. 0 in.
Wheelbase..	10 ft. 6 in.
Weight in working order	38 tons
Max. tractive effort	22,000 lb.
Max. speed at 850 r.p.m. engine speed	27.5 m.p.h.

Before being sent to Russia the locomotive was tested at the Krupp works, and showed a thermal efficiency at the rail of 27·2 to 30·6 per cent. according to the gear ratio employed.